

TandemTable: Supporting Conversations and Language Learning Using a Multi-Touch Digital Table

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ABSTRACT

We present TandemTable, a multi-touch tabletop system designed to break down communication barriers between partners, with a special focus on supporting those who are learning languages. The design was guided by a grounding study of a real-world tandem language learning (TLL) environment and refined with an exploratory study of an early prototype. TandemTable facilitates and supports conversations by suggesting topics of discussion and presenting partners with a variety of conversation-focused collaborative activities, which consist of shared digital topical content that is dynamically downloaded from the web. Through a formal study comparing TandemTable to the baseline TLL condition of no support, our system was shown to increase communication between learning partners, reduce social discomfort, and was the preferred way of engaging in TLL.

Index Terms: K.3.1 [Computers and Education]: Computer Uses in Education—Collaborative learning

1 INTRODUCTION

Language and culture are integral to the human experience; they define our customs, traditions, and how we communicate to one another. It is estimated that half of the Earth's population speaks more than one language [38], which is reinforced by many governments recognizing two or more official languages.

Bilingualism has been associated with “increased attentional control, working memory, metalinguistic awareness, and abstract and symbolic representation skill” [1], as well as health benefits [7]. There exist many language learning methods to help learners, including computer assisted language learning (CALL) [37] and tandem language learning (TLL) [16, 41]. CALL encompasses computing devices and software applications used to teach and learn languages. In TLL, two or more individuals interact and converse to improve their language skills. This collaborative learning method turns the teacher-student paradigm on its head, as each individual acts as a student and a teacher. Based on the mutual exchange of language between partners, TLL also enables individuals to learn about their partner's culture and character; facilitating intercultural learning. There are many ways that a TLL session can be structured. In the case of a dyad, both learners can learn the same language together, or each person can learn the other's first language (a language exchange).

We introduce TandemTable, a multi-touch tabletop system based on discussion activities which are designed to improve and facilitate the tandem language learning process. We contribute the design of TandemTable, a comparative evaluation of learner satisfaction and amount of interpersonal communication, and design guidelines resulting from our research. In the remaining sections of this paper we discuss related work, followed by our iterative design of

TandemTable and evaluation process, and concluding with a discussion of the results and recommendations for future TLL systems.

2 RELATED WORK

Multi-touch tabletops have been found to promote equitable physical participation (e.g., [30]), a high level of awareness, and enable fluid interactions and role switching [13]. With the appropriate software, their use has also been shown to induce enjoyment (e.g., [2]), and encourage learning (e.g., [25]).

In this section, we discuss prior work and findings related to collaboration around multi-touch tables and collaborative learning using multi-touch tables.

2.1 Collaboration Around Multi-touch Tables

Interactive tabletops have been used to support a variety of collaborative activities, e.g., brainstorming [6] and information gathering [39]. To guide the design of collaborative applications for this medium, early work was targeted at understanding how collaboration occurs around tables, and how digital tabletop collaboration can be improved. Scott et al. created design guidelines to facilitate effective co-located collaboration [32], and discovered that adults use three types of interaction areas: personal, group, and storage when collaborating around traditional media [33]. These areas have different spatial properties, as well as distinct functionality, and our design is informed by these findings.

2.2 Collaborative Learning Using Multi-touch Tables

Researchers have looked at how tables can be targeted towards facilitating and promoting collaborative learning, through applications in a variety of domains, such as math (e.g., [19, 29]), and science (e.g., [5, 31]). These interfaces have employed different strategies, from using games [24] to collaborative design activities [27], to support important learning methods, such as reflection [17]. For example, researchers have used concept maps on tabletops to support discussion, reflection, and collaborative learning (e.g., [18]).

Higgins et al. found that interactive tabletops support collaborative interactions, which result in more successful problem solving and learning [11]. Multi-touch tabletops promote on-topic and reflective forms of conversation, which are both advantageous in collaborative learning [15]. Researchers have also identified design features that promote collaborative learning through game play [2]. By creating a framework to examine collaboration around interactive tabletops, Fleck et al. revealed that some adverse interactions, in the context of collaboration, are actually beneficial for collaborative learning due to them provoking useful discussion [10].

Similar to this work, other researchers have explored using interactive tabletops for collaborative language learning. Sluis et al. created an augmented tabletop system based on matching pictures to support the development of reading skills for children [35]. In the work by Morris et al., researchers explored the design space when creating three different language learning applications that centered on matching words with pictures, sorting words, and creating free-form sentences [20]. Our system differs from these projects as it specifically targets the TLL method, and is designed for dyads of adult learners.

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3 GROUNDING STUDY: UNDERSTANDING TLL

To gain a rich understanding of the tasks and context involved in TLL, we conducted an informal grounded evaluation [14] of a real TLL environment, called the *Conversation Café*, using participatory observation and interviews. All interview participants attended the *Conversation Café* during the observed study session. Situated on our university campus, *Conversation Café* is a TLL environment designed for international students to practice their English skills and create new relationships by speaking to one another.

3.1 Participatory Observation

The participatory observation involved 16 adult participants, including one researcher and two administrators. 12 participants were male. While taking brief notes, the researcher participated in the language learning experience, which lasted for one hour and consisted of one large group conversation that was mostly question based. Due to concerns with disrupting the learning environment, only one session was studied, and the session was not recorded.

The session started with all participants seated around a large table introducing themselves. For new attendees, this introduction seemed important to their learning process, as it appeared to integrate them into the group. This integration and acceptance seemed to create a more comfortable setting for expression. Many topics were discussed including ones that related to universities and education, family and personal life, countries, cultures and recent global events.

The administrators helped to involve each participant in the conversation by starting conversations and improving the flow whenever an awkward, silent, or uncomfortable situation arose. The strategies that they employed were to expand on the current conversation topic, introduce a new or similar topic, and ask other participants questions related to the current or new topic. At the same time, the administrators did not control the conversation and kept their talking to a minimum.

3.2 Interviews

The interview portion of the study consisted of individual one hour interviews with five participants, including one administrator. We wanted to understand the participants' use of technology and experiences in language learning, with a focus on TLL. Concerning the administrator, we wanted to find out about her experience in managing the TLL environment. Two participants were female and three were male, median age 29 (SD = 13, range withheld for participant privacy). All interviewees considered themselves fluent in at least two languages. Participants were interviewed individually by the same researcher who conducted the participatory observations. Responses were recorded in note form and summarized under four themes in the remainder of this section.

Language Learning Experiences: Interacting with other people was the most preferred language learning method used by the participants as it allows learners to receive instant feedback through facial expressions and verbal responses, familiarizes them with other people and cultures, teaches learners how to pronounce words and interact with others, and exposes them to different accents.

TLL Experiences: Prior to their participation in the *Conversation Café*, all but one participant had past experience with TLL. The structure of those TLL sessions varied and included informal conversations, switching between two languages after a specified period of time, and only speaking in the language that one is trying to learn. Participants also reported that there are many different ways to structure TLL sessions, and that partners do not have to be at the same language skill level. These findings expand the commonly held definition of TLL [40]. Other than the administrator, interviewees participated in the TLL environment for two main reasons: to improve their language skills and to make new friends.

Facilitating Group Learning: The administrator's stated role in the learning process agreed with our observations: to help the conversations flow, get the people who are not involved to join in, make sure there are no silent or awkward periods, and help smooth over students' speaking if they are stumbling or cannot find the right words.

Suggested TLL Activities: To improve the *Conversation Café*, participants suggested including games, such as a board game with pictures, or artifacts to help inspire conversation topics, and to split the group conversation into many smaller conversations to create a more secure context for trying out speaking skills.

To foster TLL and improve understandability and learning, participants suggested focusing on collaborative activities, especially ones with a visual component such as videos, pictures, and news articles. Pictures and videos were said to help inspire topics of conversation and match language use with the context of the situation. Activities that can cause conflict between partners, such as discussing politics and global events, were unpopular due to this possibility. Other suggested options were to include writing and drawing technology, voice analysis, dictionary and translation technology, and to support the learning of idioms and slang.

4 DESIGN GUIDELINES FOR TLL

To help people design for this language learning method, we have compiled a list of guidelines for TLL scenarios derived from our grounding study, and prior literature at the intersection of CALL, TLL and human-computer interaction (HCI) (e.g., [16, 17, 20, 23, 28, 37, 40, 41]).

Support Flexible Learning: Due to the various ways that tandem language learners structure their learning sessions, the learning environment should be flexible. To foster the different aspects of language learning, the learning environment should support reading, speaking, writing and listening, and include visual content. Learning environments should support collaboration and face-to-face communication.

Build Relationships: An initial introduction between conversation partners is important for the learning process as it allows partners to become more comfortable with each other. This creates a more secure context for trying out speaking skills, thus increasing learning participation. Also, one of the main reasons people participate in TLL is to meet new people and build relationships. Therefore, a TLL environment should facilitate and promote relationship building.

Facilitate Conversation: The learning environment should act as a conversation facilitator by helping conversations flow whenever an awkward, uncomfortable or silent period arises. It should also encourage equitable participation and aid learners when they are having difficulty speaking.

Suggest Topics: A learning environment should suggest conversation topics or themes from various domains to accommodate multifarious interests. Topics that many people find sensitive, such as politics, should be avoided or suggested with caution, as they increase the possibility of discomfort.

5 DESIGN AND IMPLEMENTATION

Interpersonal conversation is the main learning activity of TLL. Thus a successful TLL application must integrate seamlessly into the conversation, acting as a facilitator when needed, and otherwise will be *mostly ignored*. For our system, the table form factor was determined to be the best solution since people from different cultures are accustomed to using tables for collaborative group work. This is because they create a central location for congregation, support comfortable proxemic arrangements, facilitate natural face-to-face communication and afford peripheral awareness of others, their actions, and the workspace [36]. These advantages are

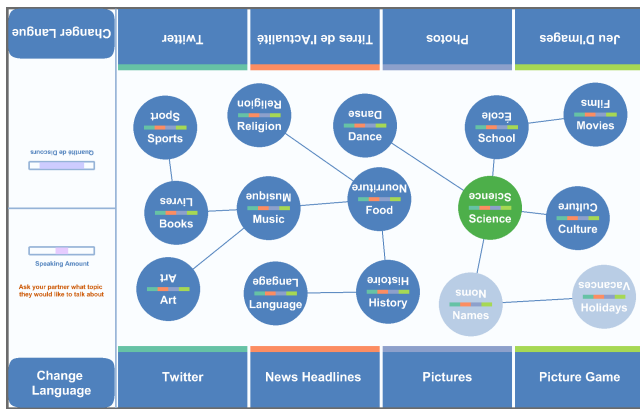


Figure 1: The main screen of TandemTable provides a selection of available conversation topics (central circles) and associated activities (rectangles along edges), and includes colour-coding to show a history of topics already discussed (light blue) and the current topic (green).

beneficial for TLL since this learning method is intrinsically a collaborative activity that relies on conversation, and observation of body language and actions.

Even though digital tablets have a similar form factor to tables and are more widely accessible to the public, we opted to not use them as their display sizes are small. Online video conferencing was not chosen as it has a lower degree of social presence [34], and less support for the use and recognition of non-verbal communication [9] compared to co-present interaction. The latter is very important since non-verbal communication has a major role in how humans express information and how that information is understood [23], e.g., deictic gestures. Furthermore, since non-verbal communication varies across cultures, language competence does not solely depend on verbal acquisition. Certain gestures, proxemic arrangements, eye gaze, etc. that are common to one culture, might be insulting or confusing to another.

Therefore, we designed an interactive TLL tabletop system, called *TandemTable*. Using our aforementioned design guidelines, the design of our system went through iterative development.

5.1 TandemTable

Since TLL relies on interpersonal communication, our system is designed to *not* be the main focus of the people that use it, staying in the background until needed. TandemTable acts as a conversation facilitator by suggesting topics of discussion, and presenting learners with a variety of conversation-focused collaborative activities with shared digital artifacts. These help to ground the conversations by establishing a theme with related content. The included topics consist of the most popular ones discussed at the *Conversation Café*, as well as in the interview portion of the grounding study.

The interface of our system is designed in order to allow the learning partners to face one another, with the interactive tabletop located in between them, to emulate standard conversation arrangements. To support the different interaction areas used by people collaborating around a table [33], the interface is split in half horizontally to provide learners with personal territories. The digital content in these interaction areas is oriented towards the closest learner. When a shared workspace is needed, the interface provides a group territory in the center of the screen. Throughout the interface, to promote equitable participation and discourage one user from controlling the learning session, both learners must agree and either sequentially (touch and confirm) or simultaneously (two touches) select the same button to select topics, activities, or to transition to another section.

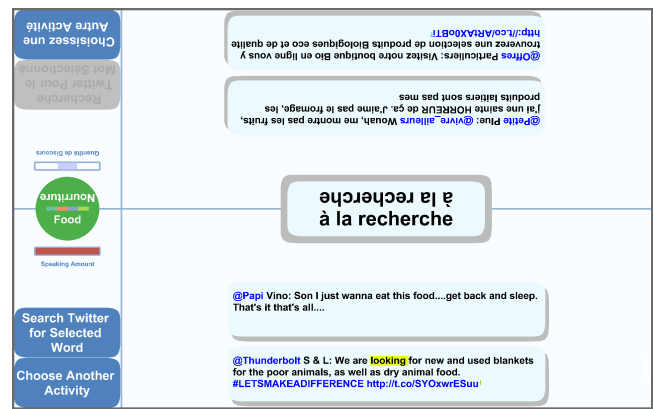


Figure 2: The Twitter activity displays recent topical content in each learners' target language. The red bar in the conversation feedback visualization in the left side panel shows a cue that the bottom participant is speaking too much.

To develop our system, we used the Java programming language, and a Processing [26] library called the Simple Multi-Touch (SMT) toolkit [22]. TandemTable also supports the TUIO protocol, which allows it to work on a variety of hardware devices. In the remainder of this section, we will describe the various features of TandemTable and how they relate to our TLL requirements.

5.2 Language Selection & Introduction Phase

At the beginning, each learner is given a list of languages from which they choose their target language. Currently, our system supports English, French, Portuguese and Spanish, but could easily scale to other languages. After one is chosen, all subsequent text and activity content in a learner's screen space is displayed in this language. To support different ways of structuring the learning session, the learner is able to change their chosen language at any time. When both learners have chosen a language, they move on to the introduction phase.

To create a more comfortable context for trying out speaking skills, the introduction phase encourages the learning partners to become familiar with each other, thus strengthening their relationship. The system prompts the learners to ask their partner a series of non-invasive personal questions, and to discuss their interests and hobbies. In TLL, each learner is responsible for their own learning. Therefore, to optimize the learning session, it is important for learners to state their learning goals and expectations, and how their partner can support them. As a result, the system prompts learners to discuss these factors as well.

5.3 Topic and Activity Selection

When the learners reach this section, an undirected graph is displayed in the center of the screen with each node containing a topic of discussion. The edges depict a suggested route that users can traverse during the learning session, and are meant to show topic relationships. For prototyping purposes, this graph is randomly generated, but in a more formal educational context, it could be used to depict the curriculum and the path that students must follow (see Figure 1).

Learners first select a topic of interest. When selected, the topic's available activity buttons are enabled, and the learners can select an activity. Not all activities are available for each discussion topic as some activities do not function well with certain topics, e.g., a topic such as books might not be well suited for a video-based activity. A multi-coloured bar inside each topic node provides a preview, both spatially and through colour, of which activities are available for

that topic. When both learners have selected the same activity, the system transitions to the selected activity screen.

5.4 Activities

To inspire conversations, the system includes five different media activities: videos, pictures, news articles, word-to-picture matching game, and Twitter. We decided to create activities which draw content from web-based sources rather than requiring teacher-curated content. Through using web-based content, TandemTable can support many languages without the need of costly teacher intervention. This approach provides timely and fresh content on each use of TandemTable with little effort, but will lack the quality control of teacher-moderated content. We rely on learning partners to assist one another in discovering when there are language errors, for example, in content drawn from Twitter. In a more formal educational context, these activities could be based on a curriculum. Since engrossing software may distract partners from interacting with each other, the activities are designed to not be too engaging, e.g., they do not keep score and are not time-sensitive.

The learners can freely explore activities, and switch topics to change activity content. We designed these activities to all have a visual component. The video and picture activities were included as they are among the most popular TLL activities chosen by the participants in our study. A benefit of the Twitter and news article activities is that they can help to improve reading skills. Likewise, the video activity supports improving listening skills. To promote understandability, as suggested by study participants, we have included translation technology in the Twitter and news headline activities.

Twitter Activity: The Twitter activity allows learners to view what other people are discussing in real-time, and exposes learners to slang and idioms (see Figure 2) as was requested in our grounding study. When the users select this activity, tweets in the target language(s) that relate to the selected topic of discussion are downloaded and displayed in each personal interaction area. If a word within a tweet is selected, it is highlighted and displayed in the center of the screen for both learners to see and discuss. If both learners do not understand the selected word, it can be translated with an additional tap. To further support serendipity, learners can search for tweets related to the selected word, and tweets from a specific Twitter user or hashtag. Also, if a tweet contains a hyperlink to a video, picture or webpage, the contents of the link are displayed when it is selected. Since videos usually contain audio content, only one video can be viewed at a time, and it is displayed for both learners if they accept to view it. To enable discussion, the video can be paused as well.

News Headline Activity: In this activity, up-to-date news articles in the target language(s) that relate to the chosen topic, are retrieved using a news feeds distributor. The news headlines from these articles are displayed in each personal interaction area. When a learner selects a news headline, the author, date, associated picture(s), and the article are shown. As with the Twitter activity, if a word within a news article is selected, it is highlighted and displayed in the center of the screen for both learners to see or translate.

Picture Activity: When users select the picture activity, pictures related to the chosen topic are downloaded from Flickr, and four of them are displayed for the learners to discuss. These pictures can be dragged, rotated, and scaled using high level gestures. To replace a picture with a new one, the learners can drag a picture into a garbage bin.

Video Activity: In the video activity, videos in one language that relate to the chosen topic of discussion are retrieved from YouTube. If two languages are being learned, the learners can select a button to retrieve videos in the other target language. Each personal interaction area contains an interface current [12], where video thumbnails appear. Thumbnails are removed or added to the currents by



Figure 3: The setup of our exploratory study, using the pictures activity. Pairs of participants used TandemTable on a large multi-touch table for 35 minutes of TLL.

dragging. When a learner selects a thumbnail, a larger sized image and the title of the video are displayed. If both learners select the same video for viewing, then the video is displayed in each of the learners' personal screen space. To enable discussion, the video can be paused.

Picture Game Activity: The picture game activity is a collaborative word-to-picture matching game. Six pictures are displayed in the center of the screen, and each of the personal interaction areas contain a list of words. Each learner's list is in their respective target language. The learners must work together to match the words to their associated picture. Each picture has two boxes attached to it, and the learners must each drag the word that matches the picture into their respective box. Learners win when they have both matched all of their words to the correct pictures. When completed, the words and pictures are replaced with another set, and the next round commences. Most of the words and pictures relate to the topic of discussion, but some do not. We made this design decision as it has been revealed that the inclusion of a few out of place words encourages learning. This is due to the unrelated words becoming more conspicuous, resulting in increased memorability [8].

6 EXPLORATORY STUDY

To see what kind of effect TandemTable has on the discussions of learning partners and their comfort level with each other, we conducted an exploratory study of our system consisting of 16 participants in groups of two. The participants were either undergraduate or graduate students comprising of 4 females and 12 males with ages ranging from 18 to 31 ($M=22$, $SD=4$). Three of the groups had no previous relationship prior to the study, and the other groups reported themselves as ranging from friends to close friends. Participants were selected to be in the study if they were trying to learn either English or French, and if that language was not their native tongue. Out of the 16 participants, five of them had previous experience with TLL, nine were fluent in one language, six were fluent in two languages, and one was fluent in three languages. All participants stood during the study sessions.

Due to difficulties finding sufficient matching pairs for language

exchange, learning sessions was structured with both partners learning the same language. Skill level was self-reported by participants using a 5-point scale, and all participants were coincidentally with partners at the same skill level. An Evolve Two multi-touch tabletop was used as the platform, as its 46 inch rectangular tabletop, at waist height, encourages face-to-face positioning and interaction and is appropriately sized for adult learners (see Figure 3).

6.1 Method

The study session lasted about 70 minutes, and started with a pre-questionnaire and pre-interview to gather demographic information. After this, the TLL method was explained to the participants. Once completed, the learning partners were introduced to TandemTable, and given a demo of each section and activity. The participants then had five minutes to try out the system and become comfortable with its features.

After this stage, participants began their TLL session starting with the introduction phase. One researcher observed the participants during their learning session, while writing notes. After using the system for 25 minutes, if participants had not attempted each activity, they were asked to do so. This was done to make sure that participants would be able to provide feedback on all features. After 35 minutes, the learning session ended with individual post-questionnaires and a paired interview to gather subjective feedback of the system, and ideas to improve it.

6.2 Results

During the learning session, six groups selected French, and two groups selected English as the language to learn. When discussing 7-point scales in this study, participant ratings of at least *somewhat agree* are taken as an indication of agreement.

Comfort and Familiarity: 6 of the 8 groups found that the introduction phase helped them feel more comfortable interacting with their partner as well as become more familiar with them. As one participant put it, “the questions broke the ice.” The other groups stated that due to their previously established relationship, this section did not improve comfort or familiarity. The activities were also found to increase levels of comfort and familiarity since partners were able to collaborate to determine the meaning of words, and the content provoked them to discuss related life experiences. Only one group, who had no prior relationship, felt moments of awkwardness or social discomfort, but they found that this was mitigated by the software suggesting discussion topics and using activities. 81% of participants indicated that TandemTable helped them feel more comfortable with their partner, and 63% found that it helped them get to know their partner.

Conversations: 94% of participants perceived that the software helped to increase the amount of discussion between partners, and 94% found that it helped them find new things to talk about. All participants stated that there were lulls in their conversations, broken by the myriad of discussion topics and requirements for users to agree to perform certain actions. It is important to note that content which was above a learner’s language skill level caused them to talk more in their native tongue and decreased the amount of interaction with their partner.

Interaction Design: 75% of participants did not find the system to distract from conversation; one participant said “...it actually makes you talk more.” One of the two groups who found the software too engaging commented that having to perform selection actions simultaneously disrupted the flow of the conversation. There is a trade-off inherent in this design decision: requiring collaboration on interaction brings partners together, but may disrupt conversation flow. We feel our design is justified as the collaborative interaction and associated negotiation can serve as a grounding reminder of one’s partner, avoiding a situation where participants

could go about independently using TandemTable without talking or working together.

Activities: The activity that was selected the most during the learning sessions was the picture game, followed by videos, pictures, news headlines, and Twitter, which were selected 13, 12, 9, 8, and 8 times respectively. In terms of popularity, the picture game activity was the most liked, with 14 participants selecting it as their favourite activity. Participants enjoyed this activity due to it being fun, inherently collaborative, and consisting of visual content that facilitated the learning of related words. The picture game also provoked the most interaction and conversation since partners had to work together to complete a level. As participants put it, “...if you didn’t know a word then ask your friend,” and “If someone did not know the answer then you had to help them.”

Learning: All but two participants (88%) thought that using our system is a good way to learn a language, all but two participants (88%) would use our system in the future for language learning, and all but one participant (94%) enjoyed using our software. When asked what aspect of the software helped to improve their language skills, participants stated that the visual content, translation ability and the features that induced more interaction between learning partners helped the most. Specifically mentioned features included the ability to highlight words for discussion and having them appear in the center of the screen, how the system suggested topics for conversation, and the content of the activities, with special attention to the collaborative picture game.

7 DESIGN ITERATION

Based on the results obtained from our exploratory study, we refined TandemTable by adding support for the Portuguese and Spanish languages, removing the video activity, and adding audio analysis with associated features.

7.1 Video Activity

We observed that the least amount of interaction between partners occurred during the video activity. This happened because learners spent their time concentrating on listening to the videos instead of conversing. To mitigate this problem, we removed the video activity entirely. Another option would be to automatically pause the video periodically and prompt the learners to explain and discuss the content of the video with each other.

7.2 Audio Analysis

We added a subsystem to record and analyze audio in real-time from two separate audio input channels, one for each learner. Collecting this data was suggested by reviewers of an earlier draft of this work as a potential way to quantitatively evaluate the impact of TandemTable on TLL conversation dynamics. In addition, with this data, TandemTable can determine when neither of the learners are talking and perform different types of actions depending on the state of the system. To analyze the audio signal, we implemented the voice activity detection algorithm explained in the work by Ogawa et al. [21]. This allows the system to determine the length of each utterance, and the number of utterances for each learner. The reported parameters values in the following subsections were chosen based on pilot testing.

7.2.1 Conversation Prompts

To further help promote discussion, we included textual and audio conversation prompts. If neither of the learners have spoken for 30 seconds, subtle textual prompts fade-in and out at the side of the interface. These prompts suggest different questions and examples of things to discuss. If neither of the learners have spoken for 120 seconds, an audio prompt is played to remind learners that they should talk with their partner. Future work could focus on creating

a subsystem to determine if learners are speaking in their target languages, and provide either audio and textual reminders.

7.2.2 Conversation Feedback Visualization

Inspired by research involving participation balance and group discussion (eg. [3, 4]), we created a conversation feedback visualization. TandemTable displays how much each learner is speaking using centred-filling bars, as seen in the left panels of Figures 1 and 2. The visualizations are intended to promote awareness of participation and encourage learners to self-correct conversational imbalances. To determine the length of each bar, we implemented the following algorithm: Using a sliding window of 20 seconds, we determine how long each learner has spoken during that time, and perform a weighted average of its value with the value from the preceding 20 seconds. A weighted average is used to prevent a sudden drop off of the visualization. When the length of the bar passes a threshold, it turns red indicating to the learner that they are speaking too much. $S_t = 0.75 * (U_{t-W}/W) + 0.25 * S_{t-1}$, where S_t is the length of the visualization bar in percent, t is time, U is utterance length of the learner during the current sliding window, W is the sliding window length, and S_{t-1} is the previous width of the visualization bar. Another design option would be to cue the less talkative learner to participate more in the conversation.

8 QUANTITATIVE STUDY

As TLL is heavily based on verbal communication, we wanted to determine if our system encouraged conversations between partners by measuring utterance rates. We performed a comparative evaluation study with a single-factor within-subjects design. The study consisted of two conditions where participants performed the TLL method in pairs with and without using TandemTable. To mitigate learning effects, condition ordering was counterbalanced, and sessions were held at least a week apart. Our participant pool consisted of 4 pairs of students from our university ranging from 19 to 37 years old ($M=24$, $SD=5.8$). None of the participants participated in either of the previous studies. To control for familiarity of partners and language skill level, all partners were strangers before the study, and each participant was partnered with someone at the same language skill level. Skill level was determined through self-reporting on a 7-point scale. Due to the difficulty in recruiting mutually-exclusive learning pairs for language exchange at our small university, all participants were learning French. In terms of prior language experience, two participants self-reported as being fluent in one language, three in two languages, and another three in three languages.

All participant pairs stood during the study sessions, facing each other. A 46 inch LCD HDTV with a touch sensitive PQ Labs G4s overlay was placed horizontally at waist height between participants. During the no aid condition, the TV was turned off. Two 1-channel omnidirectional clip microphones, affixed on the chest of participants, were used to capture audio data in 16 bit format at 44 kHz for detecting utterances. To reduce false positives from the microphones, a noise profile was taken for each mic at the start of each study session and used as a baseline for utterance detection thresholds. Additional audio and video were captured using an HD webcam. The learners' interactions with TandemTable were logged, as well as the number and length of each utterance.

8.1 Method

The duration of each study session lasted one hour. As with the exploratory study, the first study session started with pre-questionnaires and informal interviews to gather demographic information. The TLL method was then explained in detail to participants before explaining the system, and giving a demo of each section and activity. The participants then had five minutes to try out

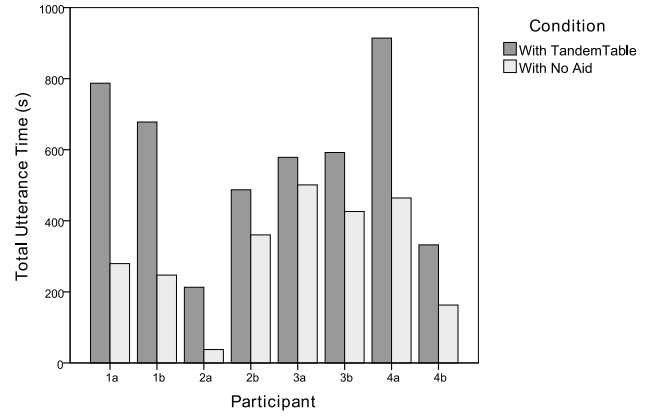


Figure 4: Total utterance times for each participant under each condition. Paired participants are labeled as a/b.

the system and become comfortable with its features. For both conditions, learners had to perform the TLL method for half an hour, then fill out individual post-questionnaires and participate in an informal paired interview. In addition, during the last session, learners filled out a comparative post-questionnaire and paired interview. To create a more comfortable experience for the learners, the investigator listened to the conversations from a connected observational room. While participants performed the study in pairs, utterance and questionnaire data was gathered on an individual level.

8.2 Results

In the following section, we discuss the results of the study. This includes the data obtained from questionnaires and interviews, as well as voice activity analysis. Our observational notes show that during the study, all participants spoke for over three quarters of the time in their target languages.

8.2.1 Utterance Time

Participants on average spoke 1.85 times longer when using TandemTable. When compared using a paired-samples t-test, a significant difference in utterance time between the TandemTable condition ($M = 573s$, $SD = 229s$) and the no aid condition ($M = 310s$, $SD = 159s$) was found; $t(7) = 4.382$, $p = 0.003$. Figure 4 shows each learners' total utterance time per study condition. Conversations in the no aid condition were, on average, 1.84 times less balanced than in the TandemTable condition.

8.2.2 TandemTable Questionnaire Results

Concerning participants' learning experience with TandemTable, seven (87.5%) thought that the textual prompts were helpful to find things to talk about; seven (87.5%) found the visualization helpful; five (62.5%) participants thought their speaking amount was influenced by the conversation visualization; and five (62.5%) found that the visualization helped them have a more balanced conversation with their partner.

Participants were asked which activity they enjoyed the most, and to rank them on a scale from 1 to 4 with number 1 being their favourite activity. Both the Picture and the Picture Game activities tied for first ($M = 1.5$, $SD = 0.5$), and the Twitter and News Headlines activities tied for second ($M = 3.5$, $SD = 0.5$). When asked which activity or phase stimulated the most interaction between partners using a scale from 1 to 5, the introduction phase had the best score ($M = 2.0$, $SD = 1.4$), with the Picture activity in second ($M = 2.1$, $SD = 0.9$), the Picture Game activity in third ($M = 2.5$, $SD = 0.9$), followed by the News Headlines activity ($M = 4.1$, $SD = 0.9$), and finally the Twitter activity ($M = 4.3$, $SD = 0.8$).

Statement	No Aid		TandemTable	
	Mean	SD	Mean	SD
1* The learning session was fun.	4.13	1.96	6.25	0.89
2* I did not experience any social discomfort during the learning session.	2.63	1.92	5.50	1.41
3* It was hard to find topics to talk about.	5.00	2.00	2.38	1.30
4 It was hard to keep the conversations going/flowing.	5.13	1.81	3.00	1.77
5 It was easy to talk to my partner.	3.88	1.96	5.00	2.07
6 There were many lulls in the conversation.	5.25	1.16	3.88	1.96
7* I experienced nervousness or anxiety during the learning session.	4.63	2.00	2.63	1.06

Table 1: Questionnaire results. Scale ranges from strongly disagree (1) to strongly agree (7). Significant differences noted with asterisks.

8.2.3 Comparative Questionnaire Results

At the end of the study when comparing 7-point Likert scales gathered from each study session, six (75%) participants found it easier to talk with their partner in the software condition; all (100%) thought that the software helped them talk more with their partner compared to when there was no software; six (75%) found that the software allowed them to get to know their partner better when compared to when they talked without the software; when employing the TLL method, all (100%) would rather use the software than having no software; seven (87.5%) felt that using the software with TLL is a better way to learn a language, compared to TLL without the software; all (100%) enjoyed the learning session with the software more than the learning session without the software; all (100%) found that the software helped them find more topics and content to talk about with their partner when compared to not having the software; six (75%) believed that improving their language skills was easier when using the software compared to not having the software; seven (87.5%) perceived themselves as learning more in the software condition; six (75%) felt less social discomfort during the learning session with the software; and all (100%) found that it was easier to keep the conversations going/flowing during the learning session with the software.

After completing each study session, participants completed a questionnaire where they were asked how much they agreed with certain specific statements, which are listed in Table 1. Wilcoxon signed-rank tests showed that there are significant differences for statements 1 ($z = -2.232, p = 0.026$), 2 ($z = -2.379, p = 0.017$), 3 ($z = -2.388, p = 0.017$) and 7 ($z = -2.232, p = 0.026$) between test conditions, and all were in favour of TandemTable.

Concerning the conversation visualization, one participant stated “Of course that feedback was very important. It gave you an incentive to be more involved in the conversation.” One participant stated “It was hard to think and it was uncomfortable” when discussing their learning experience in the no aid condition.

When discussing TandemTable, one participant stated “I think it helped a lot. I think we talked more since we had no delays. It helps with social comfort. Helps you to express yourself.” Another participant stated “The one with the software is obviously better because you don’t have to wrack your brain for conversations.” Multiple participants expressed that they felt less engaged in the conversation when TandemTable was not present. Several also stated that they found it beneficial for language learning how TandemTable grounds the conversation on a specific topic and related activity content.

9 DISCUSSION

Our exploratory and comparative studies provided helpful insights into our design and suggestions for future TLL systems. We break

down this discussion into key aspects of TLL: relationship building, facilitating conversational learning, and providing activities to assist the flow of learning.

9.1 Relationship Building

Communication is the key that enables learning when using the TLL method, and there are at least three important factors that have an impact on the amount and quality of this communication. These include the strength of the partner relationship, as well as each person’s level of extraversion-introversion and interpersonal skills. Someone who has a weak connection with their partner or difficulties in new social scenarios may have problems taking advantage of the TLL method. 75% of participants in our comparative evaluation felt less social discomfort and 75% found it easier to get to know their partner when using TandemTable. This is reiterated in the significant differences found for statements 2 and 7 in Table 1. It is important to note that from our exploratory study, three groups that considered themselves to be at least friends still did benefit from the initial introductions and found that the system allowed them to create a closer relationship with their partner. This is an indication that our system is able to promote relationship building and is useful for not only those with weak or new relationships.

9.2 Communication and Learning

A problem that occurs in TLL sessions is the attenuation of conversations, which happens in all types of relationships. Even those with a strong relationship and good interpersonal skills may find it difficult to talk with the same person for hours on end. TLL sessions can end not because the learners want it to, but due to neither of them being able to think of anything to say. Our system is designed to mitigate this problem by inspiring conversations and helping them flow. All participants found that the software succeeded in this regard by indicating that it helped to increase the amount of discussion, helped them find more topics and content to talk about, and found it easier to keep the conversations flowing with their partner. It was found to be significantly harder to find topics to talk about in the no aid condition. In fact, learners talked for 1.85 times longer when using TandemTable. It is significant to note that the audio reminder to resume conversation, triggered by 120s of silence, was only played once during the study.

An opposite effect occurred when the content was too difficult for the learner’s language skill level. Instead of working out the meaning of the difficult content together, participants tended to attempt it on their own. Therefore, future work should include more methods that promote collaborative learning for difficult content, as well as allowing the learners to select the difficulty of the content. The latter can be achieved by requiring the learners to define their language skill level during the user registration section of the system or a pre-test, and using a form of content curation. To further support customized learning, it would be beneficial if the learners could select words or phrases that they find difficult, then in future learning sessions, the activity content could automatically be geared towards presenting these challenging words.

9.3 Activities

Out of all the activities, the picture game was the most popular. Although the conversations of participants engaging in this activity were more task-focused compared to a more natural conversation, it induced the most communication between partners. Four important factors contributed to its popularity and interaction provocation. The activity is visual, it includes different media types (text and pictures), it is a game, and learners must work together to reach a goal. If the goal of a system is to induce the most interaction and communication, then visual and highly collaborative games should be included. If supporting natural conversations is more important,

then this type of activity might be problematic as it promotes more task-based communication.

Some of the tweets in the Twitter activity were found to be problematic due to numerous hashtags, and offensive content. To resolve this problem, tweets can be filtered based on their content before displaying them to the learners. News articles that were shorter in length were favoured over longer ones because less time was required to understand the main idea of each article. A future version of this activity could use natural language processing to extract a gloss of each article, to display before showing the full article.

10 CONCLUSION

To determine how we could use technology to support conversations as well as the TLL process, we conducted a grounding study of a real-world TLL environment, and produced resulting design guidelines for TLL scenarios. These guidelines can help to inform future work that make use of technology to support the TLL method. With this understanding, we designed and implemented TandemTable, a multi-touch interactive tabletop system that facilitates and supports communication exchange between conversation partners. To explore the effects of our system, we conducted an exploratory design, followed by a design review, and an empirical comparative study. Our study results show that our interactive activities and visual cues of conversation participation significantly increased utterance rates, and learners reported less discomfort and greater enjoyment.

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